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Writing to Learn Quantitative Analysis: Doing Numbers with Words Works!

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Background

While all institutions of higher learning value writing, each institution manifests its values in different ways. Indiana University Purdue University Indianapolis (IUPUI) has established an Office of Campus Writing, with a Director to design and offer faculty development opportunities to integrate writing more meaningfully and more effectively in the curricula of the 21 academic and professional schools that comprise the campus. One major faculty development offering is the annual two-week intensive Summer Faculty Writing Forum. This Forum accepts up to 15 faculty each year from schools and disciplines across the campus. These faculty, more used to the role of writing to demonstrate learning, investigate the capacity of writing to communicate learning, enhance learning, improve critical thinking, and reflect upon and evaluate learning. They design writing assignments, develop rubrics, and explore how to respond to written work more effectively. Upon completing the Forum, all faculty are asked to apply what they have learned to their own teaching, and to disseminate successful applications among their colleagues. This article focuses on the three-semester application of one Forum participant, an application that has evolved into a research project that clearly demonstrates the power of writing-to-learn to improve student understanding of quantitative analysis. It traces this evolution through e-mail exchanges between a professor of Computer Technology (Bob) and the Director of Campus Writing (Sharon).

September 1998

Hi, Bob. I thought I would check in with you to see what you have been doing in your classes with writing since the Summer Faculty Writing Forum. You mentioned something in passing the other day about having

students write explanations for each other. Can you tell me more about that?

September 1998
Sure thing, Sharon. While attending your workshop, I picked up on something one of the attendees said (I think he was a mathematics professor) about sometimes writing test questions that required students to explain a process rather than perform it to demonstrate their competence and subject mastery. I thought, at the time, "What a novel and intriguing idea. I wonder why I have never tried that." I filed the notion in the darker recesses of my mind for further exploration. Later in the same workshop, I recalled discussions I had had with Barbara Cambridge concerning the use of dialog journals in the classroom. While this vehicle had always appealed to me, on the occasions when I had initiated such communications with my students, they seemed unwilling or uninterested in pursuing an extended interchange of ideas. The idea of combining dialog journals with questions that required explanatory responses seemed to me to be two ideas waiting to be introduced to each other.

By the time your workshop had ended, I had the germ of an idea as to how to proceed. I would write a question on the chalkboard and ask each student to answer it in the best manner possible without consulting any references. This would come immediately after I had presented a concept and thus, the responses might also serve as feedback on the effectiveness of my delivery, the level of student attentiveness, and so forth. In any event, once the responses were written, I would have students exchange papers. They were then to take these papers home, research the correct answers, and critique and correct (if need be) their "partner's" answer. Papers would be returned at the next class period with time allowed for each pair of students to discuss their reviews with each other. Afterwards, students would be instructed to rewrite their journal response correctly and these rewrites would be the ones I would collect and review for accuracy.

About a week later, I would spring an unannounced quiz on the class to determine whether they could apply the concepts they had recently explained. The final test would be based on an examination performance. This seemed like a good strategy to both engage students in helping each

other to learn by making everyone both teachers and learners, but they would accomplish these activities mainly through their writing. Now I need to decide what kinds of questions to ask. They have to be pointed without losing their conceptual focus.

October 1998
Sorry to have taken so long to get back with you. That sounds as though it could be potentially very beneficial to your students. I have some questions to help me understand more clearly:

1. You mention having students write a response to a question you pose after having taught them a concept in quantitative analysis. Later, you refer to students as having "explained" something. Is the initial question one that requires some sort of explanation on the part of the student? Where does the explaining occur?

2. Have you noticed any impact of this writing strategy on the quizzes you have been giving?

3. When you refer to "the final test" based on examination performance, do you mean the final test of the efficacy of the writing strategy? Or simply that the final test of their understanding of quantitative analysis will be an examination? Or a combination of both? It would be wonderful if you came up with some hard data to support improved understanding of these concepts. I don't know if you could stipulate a causal relationship, because there are so many variables involved, but it would be very exciting if you could demonstrate some kind of link between your dialog journals and improved understanding.

I think combining the notion of dialog journals with explanatory writing-to-learn assignments is an excellent idea. What kinds of questions have you been asking the students?

October 1998
Since our last communiqué, I have given the questions and journaling considerably more thought. We are actually experimenting in class with a small band of topics. Results thus far are few, but they are promising.

Let me clarify a few points and try to answer your questions.

I first explain a concept in class in both theoretical and concrete ways. Students are taught an underlying concept and then shown how the concept can be applied in a specific case. It is at this point that I initiate the journaling process. I settled on posing two questions to my students: the first asks them to explain how to solve a particular kind of problem while the second question asks them to perform a computation to produce an indisputable answer to a specific mathematical problem. For instance, the two questions I used three weeks ago were:

1. Explain how to convert any base ten integer into its equivalent base eight value.

2. Convert (2164)10 into its equivalent value in base eight.

The answer to the first is algorithmic and may or may not be tinged with theory depending upon the approach taken by the student. The second requires a specific answer, in this case, only the number (4164)8 is correct.

After the students have had a few minutes to respond, they exchange papers with their (classroom) neighbor. The students then take these papers home, research the correct answers and critique their classmates. In most cases, the students are able to correct the work of their classmates accurately. About a week later, I gave everyone a short quiz to see whether they had mastered the computational part of the exercise. Despite the fact that most students seemed to get the journal questions correct, there was a bit of backsliding and only about 60 percent of the students correctly answered the quiz questions. But there is a happy ending to this particular tale.

Last week, I gave the class its first examination. Sharon, would you believe that 90 percent of the students successfully answered the questions relating to number system conversions? This compares most favorably with a historical trend of only 68 percent mastery for the same fundamental concepts. I attribute some of the improvement to increased emphasis on my part. Still…

The examination performance constitutes what I called previously the "final test." It really is too early to assess whether the efficacy of the writing strategy is significant, but I should have enough data by semester's end to at least suggest a tentative conclusion. I have already settled on two more sets of questions for the remainder of the course. Each set of questions will increase noticeably the level of difficulty of the previous pair of questions. As for causal relationships – well there are some statistical measures that could give us a degree of confidence concerning the success writing has in improving the students' ability to learn, but it will likely take a few more semesters' worth of data before we will be in a position to release some possibly significant findings.

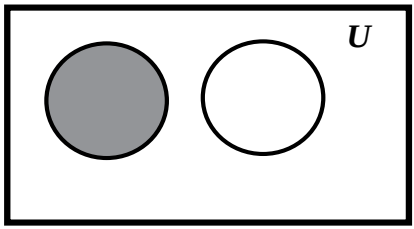
November 1998
Bob, this is exciting news indeed. I acknowledge your concern that the positive results may be attributable in part to the extra attention given to those particular kinds of quantitative analysis tasks, but, even so, that says something about the power of writing to enhance learning. Here's what I would like you to do, if you have the time.

First, do you have any information from previous years on students' typical examination performance and proficiency in the analytical tasks you are foregrounding? If so, could you compare those results with this semester's results? You refer to differences in the degree of difficulty. Would it be possible for you to select types of questions at different levels of difficulty and then compare typical performance over past years with this year's performance? I'm not sure we can jump to any conclusions, but even some preliminary confirmation might point the way to further refining your exploration of the efficacy of dialog journals to improve learning.

December 1998
Sharon, I delayed responding so that I could complete the data collection for this semester. The results have proved to be most startling so you will understand my hesitancy. But I am getting ahead of myself.

After considerable thought, I settled on two additional pairs of questions. The first pair of questions treats the probability issue of independent events versus mutually exclusive events. I considered this subject area to be of

"moderate" complexity and there certainly is a history of students confusing the two notions. Consider the following Venn Diagram:



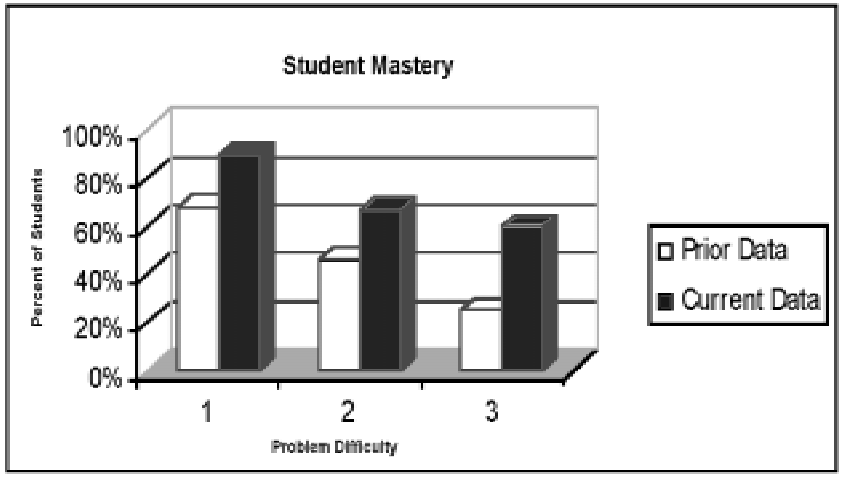
Suppose the Universe of Discourse is the Weather. The shaded circle represents days on which it rains and the other circle represents days on which there was no precipitation. Visually, the two "events" are separate and distinct. There is perhaps a visual inference suggesting independence, but such a conclusion is patently false. There is a definite relationship between the two. In fact, the occurrence of one event is totally dependent on the non-occurrence of the other. I know, this all seems so elementary, but apparently a significant number of students struggle with this distinction. As always, I coupled a question asking for an explanation of the concepts involved and one in which the students had to perform a computation to determine the existence of event dependence.

For the final pairing, I tapped into the subject of probability distributions. Specifically, we encounter binomial (two outcome) processes routinely. Binomial probability distributions are quite precise in their mathematical representations, but are often too labor intensive, if not impossible, to calculate by hand or even by computer. Under certain circumstances, the mathematics associated with either the Poisson probability distribution or the normal (bell-shaped) distribution can be used to approximate the binomial process. Although the solution method is quite algorithmic, students have a tendency to learn one or two methods to solve a problem and try to make do with them. While the need for the labor-saving approximations is appreciated, the very concept is counter-intuitive to a group of students schooled in the precision of algebra, trigonometry and calculus. In any event, historical results suggest that either I am failing miserably as a teacher or the students are having difficulty sorting everything out. My colleagues who also teach statistics acknowledge similar difficulties in getting students to master these notions concerning approximations.

In essence, I created three categories of problems based on the relative difficulty of subject mastery:

Category 1: Low difficulty
Category 2: Moderate difficulty
Category 3: Perplexing

As the following graph suggests, there was a dramatic improvement in the percentage of students who answered the categories of questions correctly.



In all three problem types, there was a dramatic improvement in mastery. Mastery improved from 68% to 90% on the least difficult problem, 46% to 67% on the moderately difficult problem, and 25% to 60% on the problem of greatest difficulty. Although some of this improvement must be attributed to the added emphasis and continual knowledge refreshment that the students experienced, there is additional data available that is noteworthy and suggestive that there is some definite merit to what we are attempting.

At the end of the semester, I asked my students to submit a minute paper containing their candid thoughts on the assignments. All of the students

were supportive, were pleased that the writing itself was not being graded, and all felt this a worthwhile endeavor that should be expanded. Some were contrite and admitted with regret that they did not put forth their best effort.

May 1999
Sharon, I am truly excited by the results this semester. Next semester, I am going to expand the process and encompass ten to fifteen pairs of questions. That is proceeding on a basis of one journal pairing per week, which is admittedly ambitious, and I may have to scale that volume back a bit. The students are still in virtually unanimous support of the writing-to-learn concept and its applicability in the Quantitative Analysis II course. There was one dissenter – an extremely bright student who felt (rightly so) that he had his own learning methods and didn't need these journal exercises, but he was the exception rather than the rule. Check back with me next fall to see how we are progressing. Regards.

October 1999
Hi, Bob. I thought I'd give you some time to get into the semester before checking in on your much more ambitious program. I have been talking with several people both on campus and at national forums about your work, and they are eagerly waiting the results.

By the way, have you been spreading the word about writing-to-learn among your colleagues in Engineering and Technology? I'd like you to consider doing some presentations for some of the schools and disciplines that resist writing-to-learn processes and strategies for increasing critical thinking through writing.

December 1999
Sharon, I just finished a School "Tech Talk" in which I shared my work and results with several colleagues from the School of Engineering & Technology. Definitely some interest sparked. As for this semester's progress, I wish I had some good news to report. I put an end to the journaling after about nine weeks. It simply wasn't working the way I had hoped. Some of the difficulties I encountered included:

1. A considerable number of students didn't get into the journaling

right away. They got behind and then attempted to catch up by doing two or three entries at once, a circumstance their journaling partners failed to appreciate at all.

2. Some students got three or four entries behind and instead of continuing on so that they could dialog about material currently being presented, they attempted to submit older entries even after the assessment point (the examination) had passed.

3. Some students had to travel on business and were unable to link up with their partners electronically.

4. I was remiss in getting all of the questions posted on my website in a timely manner. No excuse for that other than the usual "overworked and underpaid" diatribe.

5. Students weren't motivated to do the journaling – my fault here as I chose not to grade the writing as part of the course. I felt improved performance and higher test scores would be reward enough. My bad judgment. Amazing that after all these years of teaching that we can still be naïve in some matters.

Anyway, my students suggested that for the extended journaling to work, they would have to be graded in some way. If the work is for credit, they will do it; otherwise, well you get the picture here. I am going to reflect upon a better way to administer these journal assignments so that they will impact positively on the students' mastery of important concepts. Enjoy the holidays! I have much work to do before I reinitiate the dialog journals next semester.

January 2000

Happy new millennium! Time for renewal and new breakthroughs. I did not get to your message until yesterday, but could feel both your discouragement and resolution to solve the problems. In fact, your message shows that you have already figured out some solutions:

a) making the dialog journals comprise part of the course grade
b) developing a system where students cannot fall behind
c) developing a system where the journal partners can stimulate their fellow students to appreciate their own intellectual growth.

Like the questions you describe last semester, these fall into the easy, moderate, and very challenging categories. I look forward to seeing how you resolve the problem. Please let me know if I can be of any assistance.

December 2000
Hi Sharon. I have just finished poring over mounds of data concerning the journaling outcomes for the last two semesters. What a confusing mess. First of all, I accepted the students' suggestion to incorporate the dialog journaling into the overall course grade; in this case, the writing exercises counted 12 percent of the total course grade. Even so, response was still mixed. I assigned partners randomly, but because of the work and travel schedules of non-traditional students, responses still weren't always timely. I offered to partner for those students with unresponsive partners and that helped a little – but it also altered the quality and consistency of the overall responses. Most students acknowledged in their term-end reflective papers, that they just felt too uncomfortable critiquing fellow students – especially when they were uncertain of their own understanding of the material. We had some teams that worked quite well together; others were minor disasters.

In analyzing examination performance, there seemed to be no discernable pattern. No matter how I chose to categorize the students, some did well, others were average and others under-performed. For example, in answering questions related to topics covered by the journal questions, some who completed all journal assignments did very well, while others who also completed all the assignments fared poorly. The same results occurred among those who answered only a portion of the journal assignments. It also didn't seem to matter whether the students had a strong mathematics background or whether they were math-challenged.

I know that if I served as the journaling partner for everyone, there would be a consistency that ought to spark some enthusiasm and motivation. I simply do not have the time. What I need is a Teaching Assistant. Hmmm.

March 2001
Sharon, I made one major change to the experiment. I was able to hire a student to help me with the journaling. Essentially, I trained her in the basics of dialoging and providing stimulating responses to student writ-

ings. So far, things have proceeded far more smoothly. She has some natural writing ability that helps. This semester, I am able to collect students' journal entries, give them to their journal partner (my assistant), and she is able to complete the evaluation of work for about 80 students in time to allow me to review and supplement the responses before returning them to the students, usually by the next class period.

Most of the students seem to be much more enthused with this arrangement. I still have some slackers, but I have been conscientious about sending email to those students who have fallen behind in an effort to encourage them to submit their journals. Although this group of students doesn't appear to be any more intelligent than those of previous semesters, I have noticed a startlingly improved performance in their first examination. Last semester, the class average was a 76; this semester, the mean for the same type of examination was an 83. That is significant, and by any measure, this new data strongly suggests rejecting any hypothesis that suggests an examination norm of 76. There is still the possibility of a statistical aberration, although this seems a slim possibility indeed. I eagerly await the opportunity to compare examination performances for the next two assessments. We may have found some conclusive evidence that writing can help students improve their mastery of quantitative concepts.

March 2001
And that last sentence says it all! Wonderful work, Bob!